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Recognition-Primed Decision Strategies: First-Year Interim Report

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Klein Associates, Inc.

for

Contracting Officer's Representative
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Basic Research
Michael Kaplan, Director

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For this research, the goal of the first year was to expand our understanding of recognitional decision making specifically in terms of how situation assessments are communicated. Three studies were proposed. We have completed two of them and have initiated the third. In addition, we have started a project originally planned for year 2.

The projects completed were a literature review in the area of situation assessment and a multidimensional scaling experiment of expert and novice firefighters. This experiment was one of the first to use situations as stimuli, rather than simple cues such as words. The results suggest that experienced fireground commanders do not have static schemata for firefighting situations; there was low consistency between ratings made during different sessions. In addition, the importance ratings for concepts were influenced by the goal context.

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RECOGNITION-PRIMED DECISION STRATEGIES: FIRST-YEAR INTERIM REPORT

EXECUTIVE SUMMARY

The goal of year 1 was to expand our understanding of recognitional decision making, specifically in terms of how situation assessments are communicated. Three studies were proposed, and we have completed two of them and have initiated the third. In addition, we have made an earlier start of a project originally planned for year 2.

The projects completed were a literature review in the area of situation assessment and a multidimensional scaling experiment of expert and novice firefighters. This experiment was one of the first to use situations as stimuli, rather than simple cues such as words. The results suggested that experienced fireground commanders do not have static schemata for firefighting situations; there was low consistency between ratings made during different sessions. In addition, the importance ratings for concepts were influenced bythe goal context.

Two studies were initiated, to be completed during year 2. One was a research project on commander's intent. We have hypothesized that intent statements in terms of actions to be performed will be easier to follow but will not be adaptive to changing dynamics, whereas intent statements in terms of objectives will allow more effective improvisation to meet changes in the situation. The subjects for this study will be graduate students in an M.B.A. program. The second study was an examination of errors. We have had the opportunity to study errors in team decision making in a number of contexts, and we are using these data to develop two models of team decision making, one addressing team decision errors and the other focusing on team decision dynamics in operational settings.

We also performed an entirely new task during this year--a workshop on naturalistic decision making. The workshop was held in Dayton, Ohio, September 25-27, 1989. Approximately 25 professionals working in the area of naturalistic decision making met to discuss new models and paradigms and to identify directions for future research. The majority of participants rated it as more productive than typical workshops, and it is anticipated that a book written by workshop participants will be completed by June, 1990. The book will be the first document describing the recent research and model building in operational decision making.

A number of papers have been written, submitted, and presented. In year 2 we plan to complete the two projects described above and to initiate a research project on mental simulation of options.

RECOGNITION-PRIMED DECISION STRATEGIES: FIRST-YEAR INTERIM REPORT

INTRODUCTION

The importance of this basic research contract is twofold--to extend our research on recognitional decision making into new areas, and to identify the applicability of the Recognition-Primed Decision (RPD) model for Army requirements such as training.

In its current form, the RPD model describes a general strategy for making decisions in complex settings. (See Klein, 1989, for a recent review of this work.) For the past several years, supported by an earlier basic research contract from the Army Research Institute, MDA903-85-C-0327, we have been studying command-and-control decision making and have generated a recognitional model of naturalistic decision making. We began by observing and obtaining protocols from urban fireground commanders (FGCs) about actual emergency events (Klein, Calderwood, & Clinton-Cirocco, 1986). Some examples of the types of decisions these commanders had to make included: whether to initiate search and rescue, whether to initiate an offensive attack or concentrate on defensive precautions, and where to allocate resources.

The FGCs' accounts of their decision making do not fit into a decision tree framework. The FGCs argued that they were not "making choices," "considering alternatives," or "assessing probabilities." They saw themselves as acting and reacting on the basis of prior experience; they were generating, monitoring, and modifying plans to meet the needs of the situations. We found no evidence for extensive option generation. Rarely were even two options concurrently evaluated, so that opportunities for tradeoffs between the utilities of outcomes were largely absent. We could see no way in which the concept of optimal choice might be applied. Moreover, it appeared that a search for an optimal choice could stall them long enough to lose control of the operation altogether. The FGCs were more interested in finding actions that were "workable," "timely," and "cost-effective."

Nonetheless, the FGCs were clearly encountering choice points during each incident. They were aware that alternative courses of action were possible, but insisted that they rarely deliberated about the advantages and disadvantages of the different options.

Instead, the FGCs relied on their abilities to recognize and appropriately classify a situation. Once they knew it was "that" type of case, they usually also knew the typical way of reacting to it. They would use available time to evaluate an option's feasibility before implementing it. Imagery might be used to "watch" the option being implemented, to discover if anything important might go wrong. If problems were foreseen, then the option might be modified or rejected altogether, and a next most typical reaction explored.

We have described these strategies as a Recognition-Primed Decision (RPD) model (e.g., Klein et al., 1986; Klein, 1989; Klein, Calderwood, & MacGregor, 1989). For this task environment, a recognitional strategy appears to be highly efficient. The proficient FGCs we studied used their experience to generate a workable option as the first to consider. If they had tried to

generate a large set of options, and then systematically evaluated these, it is likely that the fires would have gotten out of control before they could make any decisions. Indeed, research has shown (Howell, 1984; Zakay & Wooler, 1984; Rouse, 1978) that analytic decision strategies cannot be effectively accomplished in a minute or less.

As we applied the RPD model to different settings we expanded and elaborated it. The current version is presented in Figure 1. The simplest case is one in which the situation is recognized and the obvious reaction is implemented. A somewhat more complex case is one in which the decision maker performs some conscious evaluation of the reaction, typically using imagery to uncover problems prior to carrying it out. The most complex case is one in which the evaluation reveals flaws requiring modification, or the option is judged inadequate and rejected in favor of the next most typical reaction.

The model is characterized by the following features:

Situational recognition allows the decision maker to classify the task as familiar or prototypical. The recognition as familiar carries with it recognition of the following types of information: plausible goals, cues to monitor, causal dynamics to monitor, expectancies about the unfolding of the situation, and typical reactions.

Options are generated serially, with the most typical as the first one considered. Option evaluation is also performed serially, involving testing the adequacy of the option, and trying to identify weaknesses of that option and find ways to overcome them.

A key process for evaluation is the use of mental simulations to portray the way the option would be implemented in that specific environment, to allow the decision maker to detect possible barriers or opportunities in the specific environment, and to help the decision maker improve options. Mental simulations can also alert the decision maker to important dynamics and thereby modify the situation assessment.

We do not propose the RPD model as an alternative to analytic approaches. Rather, we postulate that recognitional and analytical decision strategies occupy opposite ends of a decision continuum similar to the cognitive continuum described by Hammond, Hamm, Grassia, and Pearson (1984). At one extreme are the conscious, deliberated, highly analytic strategies such as Multi-Attribute Utility Analysis (MAUA), and Decision Analysis. Slightly less analytic are strategies such as Elimination-by-Aspects. At the alternate end of the continuum are Recognition-Primed Decisions, which involve non-optimizing and non-compensatory strategies, and require little conscious deliberation. The RPDs are marked by an absence of comparison between various options. They are generated by a starting point that involves recognitional matches that evoke generation of the most likely action in the situation.

We have tested applications of the model in a variety of tasks and domains, including fireground command, battle planning, critical care nursing, corporate information management, and chess tournament play (Klein et al.,

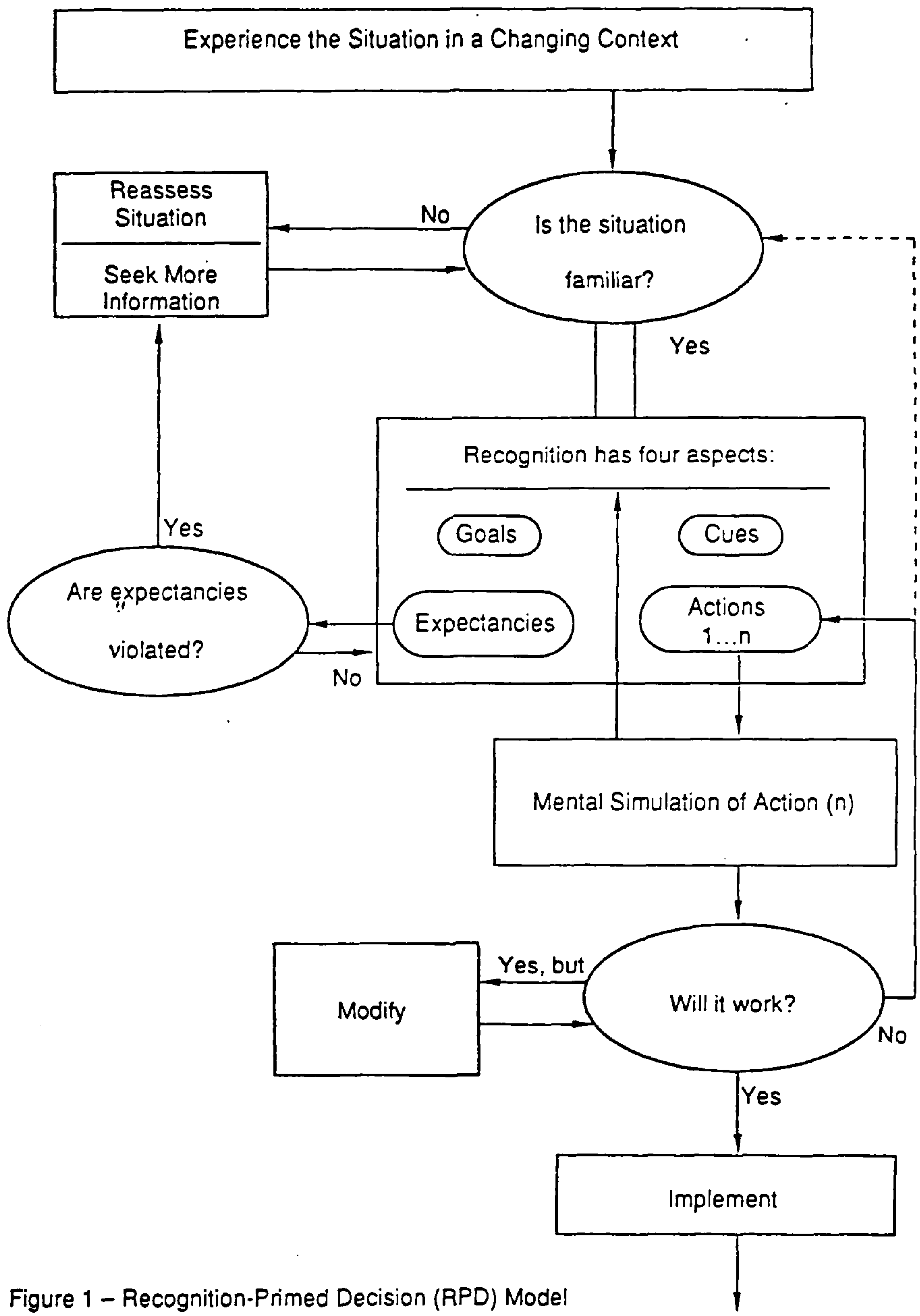

Figure 1 – Recognition-Primed Decision (RPD) Model

1986; Thordsen, Galushka, Klein, Young, & Brezovic, 1987; Crandall & Calderwood, 1989; Crandall & Klein, 1988; and Calderwood, Klein, & Crandall, 1988). These studies have shown good support for the validity and utility of the model as it applies to individual decision makers.

Goals of the Project

Three general goals are guiding this project:

(1) Evaluate the relative strengths and weaknesses of the RPD strategy. We have been primarily concerned with describing how decisions are actually made under realistic conditions. Up to now, we have had no way of determining when this strategy was ill-advised and may have resulted in less than optimal outcomes. Although we have generally been impressed with the quality of decisions made by experienced personnel under highly uncertain and risky conditions (whereas many other researchers have tended to emphasize the non-optimality and bias of human decision making), we need to put the RPD model into perspective and ask under what conditions it is non-optimal and even what particular errors and biases result from RPD decisions. We are particularly interested in examining the use of "mental simulation" as an evaluation strategy. This is the case in which the decision makers use their powers of imagination to implement an option or image in a future state of the world, and this "image" is then evaluated for desirability or sufficiency (c.f., Beach & Mitchell, 1987).

(2) Learn more about the nature of situation assessment in command-and-control environments. The RPD model emphasized the fact that decisions are not made in a vacuum. Rather, a situation is always perceived in terms of some prior experience with similar situations as a means of understanding what cues are important, what actions are reasonable, and what is most likely to occur next. We would like to develop a conceptual approach and methods for studying situation assessment processes that will prove useful to understanding and improving decision making. There are many potential points of intersection with situation assessment and psychological processes as they are studied in other areas. For example, current models of classification and categorization relate to situation assessment, but surprisingly little relates specifically to how natural, complex events are classified. Field observations and cognitive research methods will be developed and applied to investigating a) what dimensions do "experienced" and "novice" commanders use in classifying decision events, b) how do different report formats influence a subordinate's understanding of a commander's intent, and d) do some types of assessments better enable modification of plans?

(3) Explore issues related to decision quality and support from the RPD perspective. We wish to explore methods for improving decision making in operational environments that are consistent with the RPD framework and to compare these methods with more traditional (e.g., multi-attribute utility analysis) approaches. For example, we wish to learn whether it is possible to train people to make better use of their mental simulation abilities and to formulate and communicate better situation assessments. This training would impact individual decision making, but it might also have implications for

decision making in groups. As part of this effort, we will be giving attention to formulating means of measuring decision quality that make sense in command-and-control tasks. For example, there is seldom a basis for determining an <u>optimal</u> solution, and therefore measurements of timeliness, modifiability, and progressive deepening of options need to be considered.

Within these guidelines, there are a number of important and more specific questions about the processes underlying recognitional decision making, and these form much of the basis for the current 3-year research effort.

There are questions about the initial stages of situation assessment, and how it is formed, and how it is communicated. There are questions about the process of mental simulation, and how it is carried out. There are questions about the limitations of recognitional decision making, and about the types of errors that are generated by this strategy as opposed to concurrent deliberation between options. There are questions about the role of recognitional decision making in a team setting. Finally, there are questions about the guidance offered by a recognitional model in terms of training.

OBJECTIVES FOR YEAR 1

For the first year, we decided to focus on the initial questions regarding situation assessment and its communication. There has been a great deal of work on what has been referred to as the "choice point," or the "decision event." There has been much less attention to pre-decision processes, yet much of our own work, and that of other decision researchers working in operational environments, points to situation assessment as usually more important than the decision event.

Accordingly, three studies were planned for Year 1: a literature review of situation assessment, a controlled study of the concepts used by experts for situation assessment, and research on the way situation assessment is communicated in the field.

ACCOMPLISHMENTS OF YEAR 1

The first study was completed.

STUDY 1: <u>A REVIEW OF SELECTED LITERATURE RELEVANT TO THE COMMUNICATION OF SITUATION ASSESSMENT</u>

Over 20 articles were reviewed that dealt directly with topics labeled as "situation assessment" or "situation awareness." A summary of this literature was prepared and key articles were selected to be used in planning studies and addressing the situation assessment questions that we have defined. These articles were culled from a variety of sources, primarily technical reports. Many of these articles related to pilot situation awareness. Pilot situation awareness is used to define the unknown dimension that distinguishes the expert pilot. There have been attempts to measure it (e.g. Wells, Venturino,

& Osgood, 1988), train it (e.g. Lintern et al., 1987) and generate profiles of personality attributes or cognitive styles of those who "have it" so personnel can be selected with those attributes in mind (e.g. Hartman & Sechrist, 1988). Within the tactical decision-making literature, the preferred term is "situation assessment," and this term seems to fit more closely with our notions of pre-decision processes. Many investigators in this area are adopting notions from schema and script theory (Noble & Truelove, 1985; Smith et al. 1986) and some of these ideas are being used in designing our study methodologies. Some of this work has been directly guided by recognitional models of decision making and we are continuing to track potential sources.

The second study was also completed during Year 1.

STUDY 2: <u>DIFFERENCES IN THE KNOWLEDGE REPRESENTATIONS OF EXPERT AND NOVICE FIREGROUND COMMANDERS USING A CLUSTER ANALYTIC APPROACH</u>

This study was planned during Year 3 of our previous ARI contract MDA903-85-C-0327 and was completed during the current contract. Thirty-two firefighters (16 "experts" and 16 "novices") from urban departments in Ohio participated in this study. Subjects provided pairwise relatedness ratings for 231 pairs of fireground concepts (set of 24 concepts) in two separate sessions separated by approximately two weeks. Prior to performing the ratings, a specific context was created by having domain "experts" and "novices" first participate in one of two simulated fire incidents that represented substantially different types of tactical problems. Rating context was held constant for one group of subjects and was varied for another by showing the same scenario or a different one in the sessions.

A network scaling approach (Pathfinder) was used to analyze the resulting "distance" matrices for all of the individual subjects as well as matrices based on group-averaged data. Selected analyses were also carried out using multiple dimensional scaling (MDS) analysis. While it had been predicted that the across-session ratings in the context-consistent group would show higher agreement (using three different agreement indexes) than those in the context-varied group, this result was not obtained. The context of the rating task did not appear to affect the specific ratings given to the concept pairs, suggesting that such ratings are tapping relatively context-independent knowledge. In contrast, importance ratings of the concepts carried out prior to the relatedness ratings did show effects of the specific scenarios. Overall, the agreement between subjects' Session 1 and Session 2 ratings were unexpectedly low. The implications of this result for human factors applications were explored.

A content analysis of the Pathfinder and MDS solutions provided suggestive evidence of differences between personnel with more and less experience in this domain, although the differences were not as striking as those found in similar studies. We interpreted the differences as reflecting learning of functional relationships between concepts. In the Revised Research Plan we proposed to examine a group of subjects who were more truly "novices" than the firefighters studied here, who all had had over 5 years of operational experience. This would have allowed a more powerful test of the

idea that concepts are progressively redefined in terms that reflect their tactical implications. However, upon further consideration it seemed to us that this avenue of investigation was not yielding sufficient information about situation assessment or its communication to warrant the additional expenditure. We would still like to do the study, but in prioritizing our interests, there were other projects that came out higher. Portions of this study comprised the doctoral dissertation for Roberta Calderwood, granted by the University of New Mexico.

The third study was initiated but will not be completed until Year 2.

STUDY 3: THE EFFECT ON PERFORMANCE OF THE STRUCTURE AND CONTENT OF COMMANDER'S INTENT STATEMENTS

We performed field observations of brigade-level exercises of the 54th Mech Division at Ft. Stewart (June 6-12) and National Training Center exercises at Ft. Irwin, California (August 8-17). While these were not classical experiments, they were important in shaping our thinking. Initially, we believed that the communication of situation assessment was often inaccurate, and we felt that by observing errors we would gain an understanding of the process. However, at Ft. Stewart we found very few errors. Instead, the point of vulnerability appeared to be the way that situation assessment, and particularly Commander's Intent, was communicated. If the intent was communicated in terms of a series of actions (as we had earlier observed during corps and division-level exercises at an Advanced Warfighting course at the Command and General Staff College, Ft. Leavenworth, KS) then there was little room for improvisation as the battle conditions changed. Examples are shown in Table 1A. On the other hand, if intent was communicated in terms of higher-level goals, as we saw at Ft. Stewart (see Table 1B), then there was a much higher level of effective improvisation. This hypothesis was informally confirmed by our observations at Ft. Irwin, and we have presented these findings at the 1989 MORS conference, held at Ft. Leavenworth, KS. These have led to formulation of hypotheses about how the form and content of Commander's Intent statements might influence decision performance during battle planning.

Based on these observations and a search of relevant literature, a preliminary research design was formulated to study the two types of intent statements in a simulated Army scenario.

The research design addressed several questions: What are the nature of performance differences under action- versus outcome-based Commander's Intent statements? Does one of these formats facilitate a more complete match between the performance of subordinates and the actual intentions of the commander? Of particular interest are situations where preplanning is overtaken by current events and success depends upon implementation of an improvised plan of action.

Table 1A

COMMANDER'S INTENT

Ft. Leavenworth, Command and General Staff College, P318, Combat Operations,

Lesson 7

Division to Brigade

Attack in zone

through elements of the 23rd Armored Division

to linkup with 1st Frigade, 21st Infantry Division

and secure objective snake

to assist passage of the 23rd Division

and then follow and support the 23rd

to facilitate the corps exploitation

Table 1B

COMMANDER'S INTENT

Ft. Stewart, I-64, Frago 3, DIS (ARTEP Maneuver, 2nd Brigade of 24th Infantry Division)

Brigade to Battalion

The Division must protect Claxton and the major surrounding road network

for reconstruction for future offensive operations

You must not allow the enemy to penetrate Phase Line Martini

Reposition as necessary, do not get bypassed

Success is when we have destroyed all enemy in sector and have consolidated to meet follow on echelons

The research was designed to test several hypotheses:

H1: Outcome-based Commander's Intent statements result in truer matches between the performance of subordinates and the actual intentions of the commander in situations where improvisation is required.

H2: Action- and outcome-based Commander's Intent statements will result in comparable matches between the performance of subordinates and the actual intentions of the commander in situations where improvisation is <u>not</u> required.

H3: The offensive/defensive nature of the scenarios will have no effect on the trueness of match for either the improvisation or non-improvisation conditions.

H4: Impact of action- vs. outcome-based Commander's Intent statements will vary depending on the experience level of personnel attempting to implement the operations order. This possibility was suggested to us by Fireground Command trainers at the National Fire Academy who have found they must alter the format and content of orders depending on an FGC's experience level.

As originally proposed, we intended to carry out this study using a command-and-control task. In preliminary work, three types of intent statements for use in this study were developed: action descriptions, specific outcome descriptions, and global definitions of success. We also began development of scenarios based on operations orders, maps, and overlays from an actual field exercise. Permission was sought to use students at the Command and General Staff College (CGSC) as subjects in this study. We had worked before with instructors at CGSC and were optimistic that permission would be received. Plans were to run subjects during the Spring and early Summer and complete the project by the end of this contract period. Unfortunately, there were practical barriers to the use of subjects at the CGSC, creating not only a delay but an increase in the cost of the research.

Since this experiment is so important to our understanding of situation assessment, we decided to press on by shifting domains. The research is currently planned to address executive decision making in a corporate environment. We will be contrasting expert-novice performance, using simulated business exercises. The subjects will be graduate students at Wright State University, enrolled in an MBA program. The "experts" will be students with considerable business experience who are returning for a degree, and the "novices" will be students entering the program directly upon completion of the B.A. or B.S. This will be a cleaner expert/novice contrast than we could have achieved using Army officers as subjects. The major objectives of this research will otherwise remain the same.

ADDITIONAL WORK

We have performed several more projects that were not originally scheduled for Year 1.

STUDY 4: AN INVESTIGATION OF ERRORS IN TEAM DECISION TASKS

The study of errors originally planned for Year 2, has been moved ahead into the current period. The impetus for this change was several projects carried out this year for the Department of Energy, NASA, and a separate contract with ARI (MDA903-89-C-0077). These efforts have provided databases that contain much richer information on decision errors than we previously had available in our own data archives. A description of this effort follows:

Study Goals

The purpose of the study is to develop a basis for classifying errors that occur in decision tasks taking place in four operational environments characterized by their involvement of teams, high uncertainty of critical information (situation assessment), high risk consequences, and time pressure. Four databases were selected from previous studies, two of which were carried out for ARI, one for NASA/Ames, and one for the Department of Energy's Central Training Academy. Details of these databases are provided in the paper "Cognitive Processes of the Team Mind" (Thordsen & Klein, 1989). The goal of this study is to develop a taxonomy of team decision errors. This project will also serve as the Masters thesis for Marvin Thordsen.

It is important to us to be studying team performance at this point. Much decision making occurs in a team concept, and we need to understand how the RPD generalizes to team decision making. Team decision making was not an original component of our research plan, but we have become excited at the opportunity for progress in this area.

Thus far, based on preliminary analyses, we have developed two new models of team decision making: A model of team decision errors, and a model of team decision dynamics relying on the metaphor of a team mind. These two models will be described below.

Model 1: Team Decision Errors. Here, we are attempting to explain how team functioning can degrade decision performance. Specifically, we have been developing a model of team decision errors linked to barriers in recognitional decision making.

The majority of research efforts on errors has concentrated on individual rather than team errors. For example, an individual reading a gauge incorrectly is an example of an individual error, while the three members of an airline crew having different understandings of the functional state of the aircraft's generator system is a team error. We have attempted to develop a team decision error model (Klein & Thordsen, 1989). Figure 1 has diagrammed the RPD model for individual decision making. This model can be extrapolated to the team setting. Thordsen et al., (1988) found that 26 of 27 decisions identified in a five-hour Army battalion-level planning exercise followed the RPD model rather than any concurrent option analysis models. This was surprising to us, as we had anticipated that teams would show more classical patterns of generating several options and analyzing these on fixed

dimensions. We found that the RPD model for individual decision makers also fit team decision making--the teams were identifying prime options and progressively deepening those options just as individuals do.

Some team functions will be hindered somewhat by the added burden of communication of intent and situation assessment, the additional members of the team simultaneously provide a wider skill/knowledge base, more eyes, ears and hands to increase their potential to handle additional workload. There is an additional tradeoff for this in the cost for coordination. Thordsen and Klein identified eight potential barriers to team decision within the team RPD model (Figure 2). These include: 1) distorted perception, 2) difficulties with situation assessment handoff, 3) difficulties in the formulation or transmission of intention, 4) directed attention, 5) missing expectancies, 6) restricted improvisation, 7) synchronization, and 8) meta-cognition. These barriers are outlined below:

1. <u>Distorted Perception</u>. Unlike an individual, a team cannot have direct access to events. Therefore, perceptual cues available to the individual, and the experience gained in perceptual learning, may be lost to the team; external events are usually not directly experienced, and the descriptions are communicated in verbally. Since these perceptions are experienced outside the team, there is the additional factor of the credibility of the information source. For example, in a battle field environment,the brigade tactical operations center (TOC) will receive reports of enemy activity from scouts and field units. The enemy activity is seldom observed directly by the members of the TOC but is experienced second-hand via radio reports from the field. These reports are the perception of the field units, and the TOC personnel may not perceive the actual activity is the same way it was perceived by the reporting unit. In addition, occasionally the credibility of the reporting individual is questioned and the TOC's perception of the information may be altered accordingly.

2. <u>Handoff of Situation Assessment</u>. This is similar to Distorted Perception, but it involves difficulties with the actual articulation and communication of the situation assessment (SA). An individual can recognize a situation, but how does that recognition get transmitted to others in the team? This is another opportunity for distortion or omission. For example, a member of the National Security Council (NSC) may assess a situation as being one where the Soviets are planning to invade Central Europe. However, this situation assessment is based on the individual's recognition of certain critical cues, etc. that may not all be that overt. Therefore, when his/her assessment is communicated to the other members of the NSC, he or she may not be able to communicate all of the key elements and cues in a fashion that adequately hands-off his SA to the others.

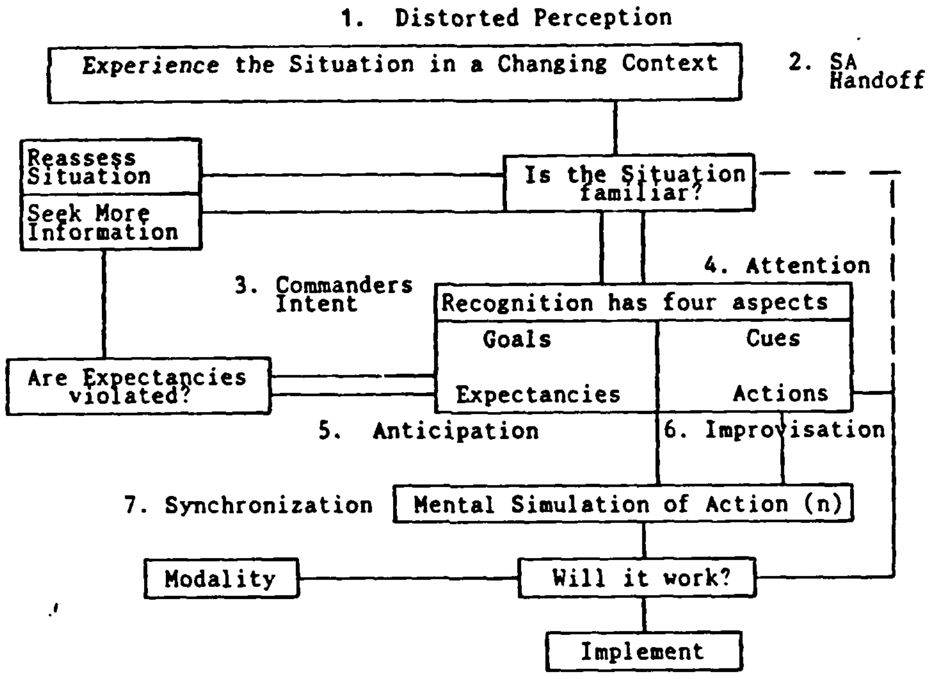

Figure 2: Seven Barriers to the Team Recognition-Primed Decision Model

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3. <u>Intent</u>. One aspect of situational recognition is the recognition of goals. An individual decision maker directly knows what the goals are in a situation. In a team, goals must be communicated and if the communication is poor, the activity of the team can become confused. It should also be noted that if the original formulation of the intent is poor, then additional problems can arise. An example of an intent-transmission problem was presented earlier, where the corps commander asked a division commander to move his troops forward to block an enemy advance. The troops had already dug in their defensive position, and would have to abandon that position to reach the proposed line of defense. Moreover, there was a good chance that the enemy would get there first. Nevertheless, the division commander issued orders to carry out the intent without questioning whether the corps commander understood the implications.

4. <u>Attention</u>. An individual naturally looks at data sources that are of specific interest to what they want to accomplish, i.e., directing attention to what is important. In a team, the data gatherers are often different from the synthesizers and planners and they may be in different places. Therefore, it is harder to get the information that is needed at the moment and it is harder to shield team members from irrelevant information that can create overloads. For example, the

Colonel commanding a brigade may, in a planning session, see the possibility of an enemy deception taking place. But because he is not in a position to attend directly to the information that would confirm or deny this, he is somewhat handicapped because he is required to take time to direct the field units on what to look for and then to wait for the reports to come back. Then, when the reports do come, many reports will probably be irrelevant, unwanted information that the commander will have to sort through to get to what he desires.

5. Anticipation/expectancy. An experienced decision maker can use expectancies to check situation assessment and to prepare for smooth reactions. In a team, these expectancies are difficult to communicate and may be missed, so team members may operate for long periods of time on outmoded and obsolete expectancies. In ineffective teams there is often little anticipation, so the team is too often behind the power curve rather than ahead of it. For example, an experienced commander will be able to sense that there aren't enough resources to carry out a plan, and will abandon the attempt very quickly, whereas a less-experienced commander might have to incur significant losses before giving up. Working in a team setting, it is harder to communicate anticipations and mismatches so that lower echelons can let a commander know when expectations are so far off that it is time to reconsider the mission.

   Expectancy errors also include inadequate time sensitivity--not appreciating how long messages and orders take to be implemented, or how long incoming messages take to be received. Moving from small- to large-scale organizations can be like the transition from steering a powerboat to steering a super-tanker. If it suddenly takes five miles to make a turn, the expectancies have to be operating much earlier than usual.

6. Improvisation. Generals know that even the best plans can become obsolete within a day or so. Individuals can quickly recognize that assumptions have failed, and can switch their assessment to match field conditions. Teams have difficulty improvising. They have trouble giving up plans that no longer make sense, and they have trouble seizing opportunities that were not expected. For instance, a battalion may be ordered to make sure that the enemy does not get across a bridge. However, upon arrival they may find the bridge undefended. Should they still set up their blocking position, or should they seize the bridge. Perhaps they should move forward. It is up to the commander to provide a sufficient overview of intent so that lower echelons can initiate actions effectively.

7. Synchronization. Skilled decision makers can play out a planned action in their heads to see if it will work. Teams try to do the same thing but they have trouble representing all the different dimensions (e.g., logistics, artillery, intelligence, weather, air support, etc.). Complex plans can be stymied by the mis-timing of only a few, sometimes

only one, of the components that must be synchronized. Synchronization implies that multiple elements and players must be sequenced in a timely fashion for all to proceed properly. In a team setting these different elements and/or phases are often the responsibilities of different team members. Therefore, the need for communication of critical aspects and needs of these different concerns is important for proper synchronization. For example, if the fire support officer does not coordinate and synchronize with the air officer in a military maneuver, aircraft could be shot down by friendly artillery.

8. Meta-cognition. Just as an individual decision maker must learn how to allocate the proper amount of resources to a task, so must a team. And it is both more important and more difficult for a team to do this well. Both the leader and the team members must be able to communicate about workload, actual and impending, so that functions are assigned appropriately, and the allocations are made in enough time to smooth the performance rather than disrupt it. The function of meta-cognition does not appear in Figure 2 because it is not a stage of decision making, but rather the management of the decision process.

<u>Model 2: The Team Mind</u>. In performing studies of team decision making, we (Klein & Thordsen, 1989; Thordsen & Klein, 1989) proposed that in a group/team setting there is an additional "individual" functioning that is best described as the result (or embodiment) of the "team mind." This is a new, preliminary model of team decision making dynamics that grew out of the conceptual work we had performed during the initial basic research contract, and came into clear conceptualization during the study of flight crews that we conducted for NASA/Ames.

The model asserts that the team mind has three aspects that can be studied: behavior, collective consciousness, and subconsciousness. These aspects will be described, along with methods for studying each.

1. <u>The mind of a team can be treated as analogous to the mind of a person</u>. The goal of this analogy is to help us understand, study, and represent the performance of a team. The unit of analysis is the team, a group of individuals with common goals and coordinated roles. A team may have extensive experience working together, or, like the crew of a Boeing 727, the members may be meeting each other for the first time just prior to takeoff. In contrast, a group of individuals may not have consensus on goals and roles so that interesting features of teamwork do not emerge. In this paper we are restricting our speculations to teams, and we are postulating that a team be treated as an individual entity capable of taking actions that depend on intentional and accidental "mental" processes. The knowledge or ignorance of a single new member is relevant if it affects the actions of the team.

2. <u>Team mind has three aspects: behavior, collective consciousness, and subconsciousness</u> (see Figure 3).

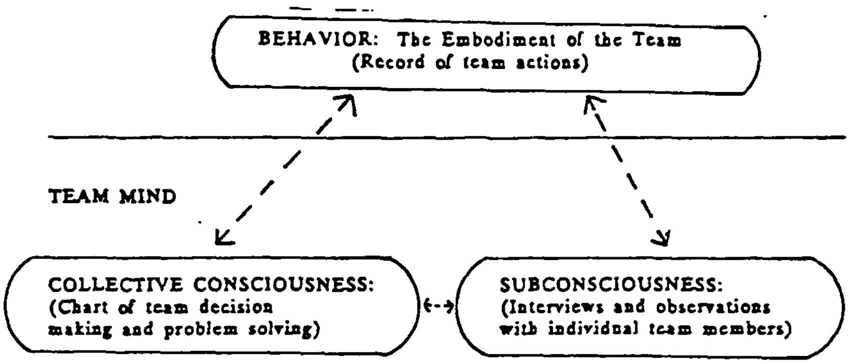


Figure 3: Three Aspects of the Team Mind

3. The team is embodied in the actions taken. The team acts, as does a person. Using the Boeing 727 crew as an example, the cockpit crew can be considered a single entity. It is the team who adjusts the controls and issues communications. Any action or message is considered to come from the single entity, the team. *The embodiment of the team is its observable*, recordable behavior. If the Air Traffic Controller issues a directive to any one of the three team members, it is assumed that the directive will be acted on by the whole team. If a distress signal is sent out, it is considered to come from the whole team regardless of which crew member made the announcement. For a command-and-control team, the embodiment is the set of plans it issues.

4. Part of the team mind is conscious and part is subconscious.

4a. The conscious part of the team mind is whatever is said out loud for all to hear. So the collective consciousness[1] of a team can usually be studied by listening. In other words, the content of collective consciousness is directly accessible while the team is performing a task. It can be studied without interfering with the task.

In contrast, the individual mind cannot be directly accessed. If you ask a person to give a verbal protocol, that will be incomplete, distorted, and will affect the way the task is performed.

We are positing a spotlight model of consciousness for the team mind, in which team members publicly share only a part of what they are noticing. For example, in our NASA/Ames study one malfunction was a leaking fuel tank. When this was detected by the Flight Engineer it was immediately brought to the attention of the other two teammates, the Captain and the First Officer. At

[1]This phrase was suggested by Judith Orasanu and her colleagues at the Army Research Institute.

that point it entered the collective consciousness of the team and we could record this consciousness on videotape.

4b. Part of the team mind is subconscious. This refers to knowledge held by one person but not shared with others. It is important to note that we are using "subconscious" to refer to any material that is fully conscious for one or more team members but has not been publicly brought to the attention of the team.

Again, the phenomenon of subconscious awareness is more easily studied at the team level than at the individual level. Videotapes and interviews will show when one team member had knowledge not available to the others. For example, in the NASA/Ames study, Crew #3, Segment #3, the Flight Engineer noticed that the number 7 slat was not extending as they were getting ready to land. He dug out his checklist before saying anything to the other two team members, who quickly detected the problem themselves. He assumed they would find the problem, and he was preparing for their inevitable request that he go through his checklist of landing problems. But until the other team members noticed the problem, it was subconscious for the team mind.

Understanding has entered collective consciousness when all or most of the team members are aware of information and/or intentions. This joint awareness is achieved by discussion, or by watching for non-verbal cues, including sounds of switches being thrown or the sounds of flap wheels turning. Cues are shared and crew members know the cues have been shared and observers can generally detect the sharing as well.

The model of team mind will be evaluated on how well it enables us to generate hypotheses about team decision performance. Our expectation is that a variety of cognitive phenomena will be applicable to the team mind, and the process of evaluating these phenomena will clarify team performance issues. We will briefly describe a number of hypotheses suggested by the model of team mind.

1. The team mind has a limited capacity for attention. Not everything should become conscious. A smoothly functioning team can take care of most tasks at the subconscious (individual) level, anticipating the requirements of other team members. Neisser (1976) described preattentive functioning at the individual level, and this is what we see at the team level as well--automatic performance of routine tasks by individuals.

2. The team mind depends on meta-cognition. Each team must manage its own activities. Anyone, usually the leader, can take steps to prevent memory overload by recording critical information. Inefficient use of collective consciousness will occur in forms such as micromanagement, and an effective team will be on guard to prevent such problems. Teams are also susceptible to interruption, and need to make sure that this does not lead to a loss of important information or disruption of action sequences.

3. The team mind is capable of errors. We can distinguish team mind errors from skill/knowledge errors of individuals, such as failure to read a checklist correctly, or mishandling a landing under conditions of cross-winds. Additionally, team mind errors are related to Model 2, team decision errors, but we have not yet attempted to synthesize the two models.

Team mind dysfunctions are errors that have to do with interactions between the three components in Figure 1. For example, in the study of Boeing 727 cockpit crews (Thordsen & Calderwood, 1989), Crew #2, Segment #3 encountered the problem of fuel leaking out of one of the wing tanks. This malfunction creates an imbalanced weight condition. But the Captain wasn't sure whether it was real failure or a faulty gauge for that tank. He asked the First Officer, who was doing the flying, "Are you having trouble flying the plane?" The reply was "No." Actually, we found out later during our interviews that the First Officer <u>was</u> noticing an imbalance, but he was able to adjust for it. So he wasn't having trouble. The Captain, who expected an imbalance, mistakenly concluded there wasn't one, and decided they had a faulty gauge.

Consider another error from Thordsen and Calderwood (1989), Crew #3, Segment #2. The malfunction was a partial loss of oil pressure in engine 3. The pressure fell to 35 psi which is on the border for shutting down the engine. The Flight Engineer wanted to shut off the engine, but neither the Captain nor the First Officer wanted it shut down. Yet the team shut it down anyway! Again, this was a failure to inhibit an impulse. What happened was that the Captain disagreed with the Flight Engineer but couldn't clearly see the oil pressure gauges which were at the Flight Engineer's station. So the Captain backed down, and looked to the First Officer for help. The Captain said "I'm recommending shutting down the engine," hoping to get an argument. The First Officer had been flying the aircraft and not paying attention to the malfunction, and took this as an announcement rather than a question, and said nothing. Since he didn't get any reaction, the Captain went ahead and shut the engine down. The action was not necessarily an error; what was significant was that the two senior officers were opposed to it but wound up implementing it.

In Crew #3, Segment #2, when the team shut down engine 3, its generator was lost to them. And generator 1 had been acting up earlier, and was on a standby status, not really functional. So the airplane was landed with only one functioning generator. In our interviews we found that the Flight Engineer knew there was only 1 generator, the Captain stated there were one-and-a-half generators (i.e., he knew that a second generator was on standby but wasn't immediately available), and the First Officer, who was actually flying the plane, believed it was a 2-generator landing since no one told him what the status was! The team did not make any behavioral error, but if they had it would have arisen from faulty communication of situation assessment.

4. The team mind has intent. It is the intent of the leader, usually the official leader. In a smoothly running team, the intent doesn't always have to be articulated. The team members will assume they understand the intent until

cues mismatch their expectations, and then they re-check their assumptions. Example, Crew #3, Segment #3, the First Officer believed he knew what the Captain wanted, and this was confirmed with each other. This intent can also be unpacked by asking each member of a team what the leader was wanting to do at a given moment.

5. A smoothly functioning team mind is seen in positive efforts to improve coordination. It is seen as anticipating the needs of others, synchronizing actions, feeling free to improvise, offering effective feedback without clogging communications channels or taking up too much conscious space.

6. The functioning of the team mind becomes more effective and efficient through training, as the team learns to perform more of the tasks at the subconscious level.

Methods for Studying the Team Mind

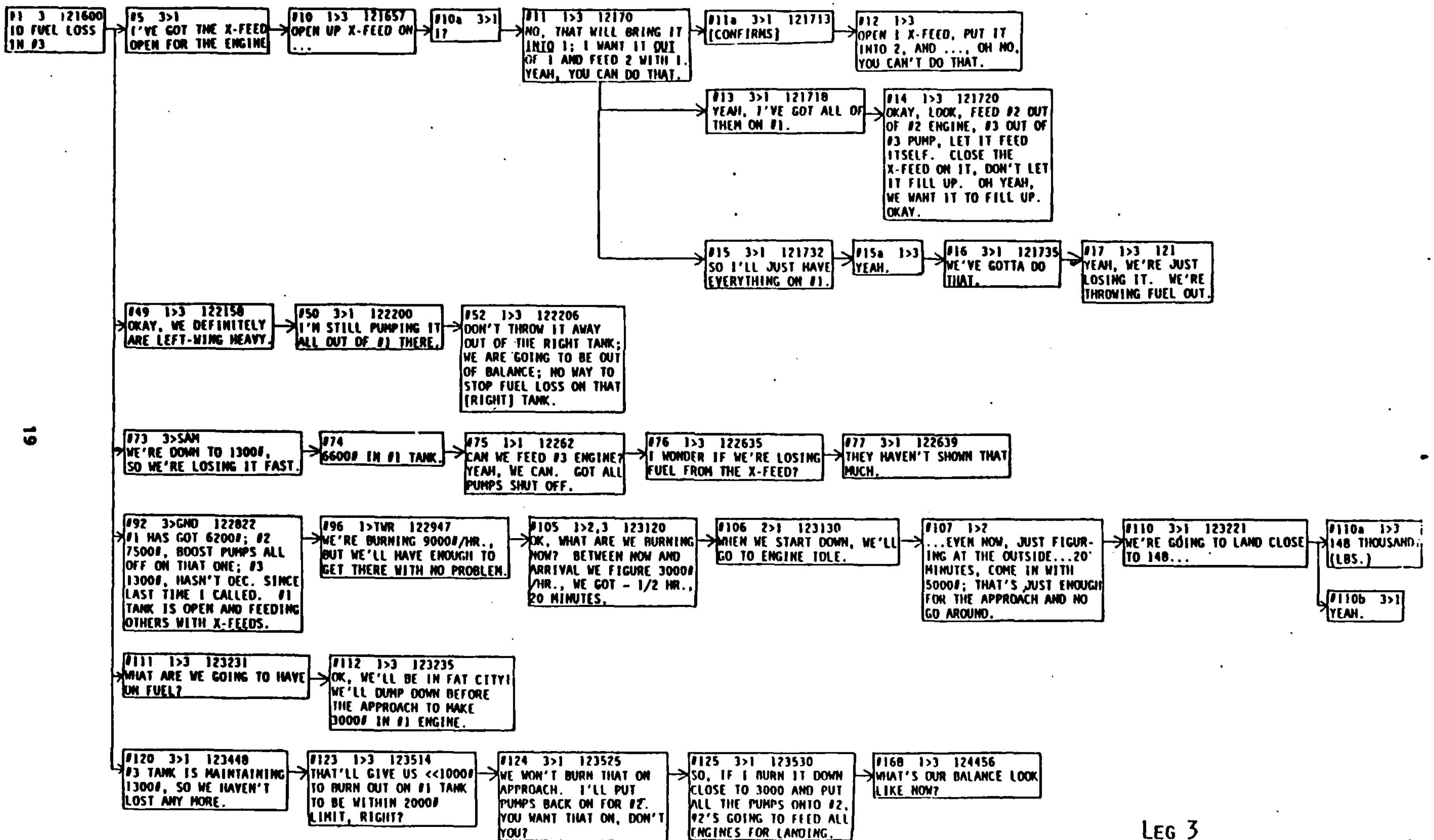
There are techniques for studying each of the three aspects of team mind: behavior, collective consciousness, and subconsciousness.

The record of the team's behavior is simply the actions taken. For a command-and-control team, it is the operations orders issued at various times during a battle. For an airplane it is the control actions taken during a flight. It is helpful to be able to link these actions to environmental conditions so that you can tell that an engine was shut down, say, five minutes after the oil pressure fell below 35 psi.

The record of the team's collective consciousness is the audiotape or videotape of what has been articulated. Since it is tedious to listen to tapes, there are advantages to charting the problem solving and decision making that the team goes through. Newell and Simon (1972) have worked out a representation of problem solving and decision making for individuals solving cryptarithmetic problems while generating think-aloud protocols. The representational charts show each action and the corresponding gain in situation assessment. We have adapted their technique for groups, and have charted planning sessions during command-and-control exercises (Thordsen, Klein, Michel, & Sullivan, 1988; Calderwood & Thordsen, 1989).

We have recently taken the team decision charts to a new level, in our recent research at NASA/Ames. To illustrate, we will use the charts for the Boeing 727 malfunction in which fuel was leaking from a tank in one of the wings. Three teams were studied. We charted the way each team developed situation assessment, and the way each team considered some key options. We will contrast the three teams with regard to how they examined the options pertaining to fuel flow. The first team, shown in Figure 4, was able to consider the option of cross-feeding the fuel from the other wing, in order to minimize the imbalance between the weights of the two wings (the recommended limit of imbalance is 1,000 lbs.). This team misunderstood the standard and thought they were permitted 2,000 lbs. of imbalance, and were able to achieve this level. The second team, shown in Figure 5, tried to do the same thing

HOW TO MANAGE - CREW 1

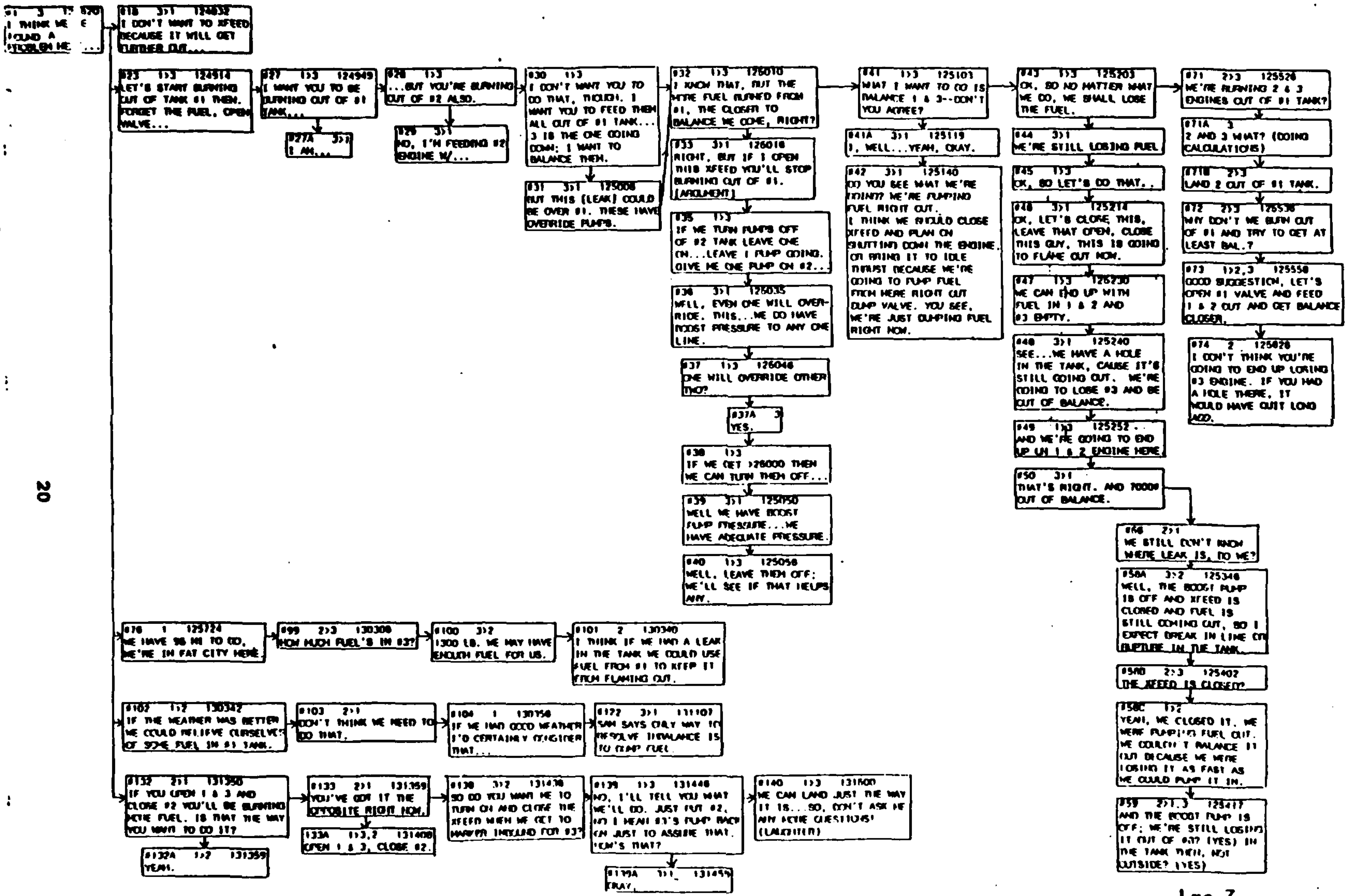


LEG 3

PROTOCOL ANALYSIS AND THE TEAM MIND
HOW TO MANAGE - CREW 1, CHART 3

Figure 4 -- Deepening the option of fuel transfer -- Crew 1.

HOW TO MANAGE - CREW 2



LEG 3

Figure 5 -- Deepening the option of fuel transfer -- Crew 2.

PROTOCOL ANALYSIS AND THE TEAM MIND
HOW TO MANAGE - CREW 2, CHART 3

but ran into a conflict between wanting to reduce imbalance and fearing the consequences of cross-feeding fuel into an area where there was an undetermined leak. The team decision chart shows the tangled arguments and counter-arguments that made up the collective consciousness. This conflict was actually between the Captain (source #1) and the Flight Engineer (source #3), with the latter operating from a faulty understanding of the layout of fuel tanks and cross-feed lines. The Flight Engineer prevailed, and this crew landed with more than a 5,000 lb. imbalance. The third crew, shown in Figure 6, was the most inexperienced, and their team decision chart reflects this--it is the most simple. They did not ever consider cross-feeding fuel to reduce the imbalance, and while they had the calmest cockpit of the three, they also landed with more than 6,000 lbs. of imbalance, the least acceptable solution. We feel that these types of team decision charts, easy to produce and indicative of the ongoing collective consciousness, will be very useful in future research and development.

The determination of the team's subconscious understanding is best made through observations of videotapes and through interviews that enable us to learn what an individual knew that was not communicated to the other team members. We have also used formal strategies, namely a Critical Decision method (Klein, Calderwood, and MacGregor, 1989) to perform cognitive probes of individual decision-making strategies.

The concept of a team mind has been introduced as a way of viewing team decision-making performance. We hope that the concept will be helpful for introducing phenomena from cognitive psychology, e.g., limited attentional resources, the effects of emotions, workload variables, automaticity, and characteristics of working memory. In addition, the model of team mind offers a range of measurement approaches that hold promise for studying and evaluating variables affecting different team performance variables. The team mind is more accessible than the individual mind. Foushee and Helmreich (1988) have recently described the importance of group process dynamics for understanding team decision making and errors, and we hope that the concept of a team mind can be useful for research investigations into these topics.

WORKSHOP ON NATURALISTIC DECISION MAKING

Besides the two studies completed, the two studies initiated, and the two models developed, one more major project was accomplished during Year 1. Klein Associates hosted an international conference on naturalistic decision making.

The Army Research Institute first suggested that it might be able to fund the workshop in February, 1989, but a contract was not signed until late July 1989. Nevertheless, we were able to perform some impressive feats of team decision making ourselves, and the workshop went off without problem at the end of September 1989 despite the limited time for planning.

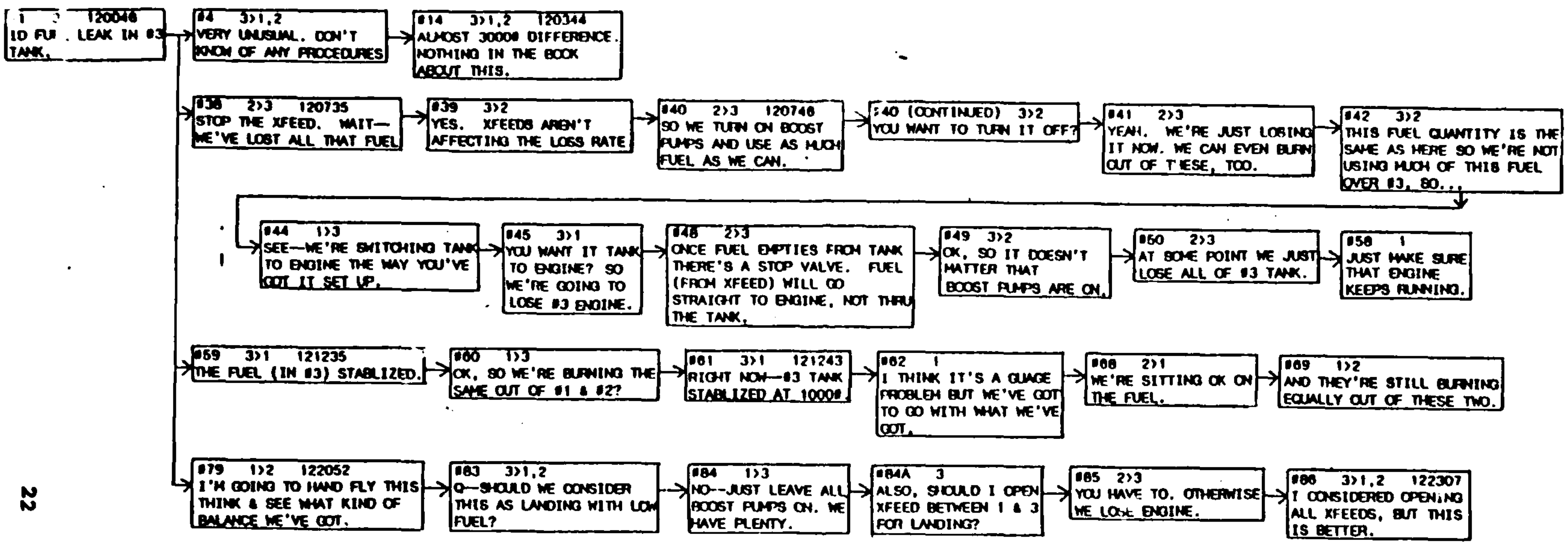


Figure 6 -- Deepening the option of fuel transfer -- Crew 3

LEG 3

PROTOCOL ANALYSIS AND THE TEAM MIND
HOW TO MANAGE - CREW 3, CHART 3

Perhaps the major function of the workshop was to bring together researchers from disparate fields who have been studying decision making outside the laboratory. In particular, a number of related naturalistic models have been put forward in the last few years, and the workshop allowed this community to take stock of what has been happening, and to explore opportunities for collaboration and synthesis. If naturalistic decision research is indeed a third wave, following the initial paradigms of mathematical and statistical decision research, then it is essential to provide such a forum, so that there will be less duplicated effort and a trading of ideas. The workshop served as such a forum. Participants from academia, industry, and the government attended, served on panels, met in small groups, and hammered out the major themes for a book on operational decision making. The completion of this book is scheduled for June, 1990. The authors will be Gary Klein, Judith Orasanu, and Roberta Calderwood.

OBJECTIVES FOR YEAR 2

During Year 2 we will be completing three of these projects.

The book, tentatively entitled "Decision Making in Complex Worlds," will be finalized and submitted for publication. (Two publishers have made a commitment to publish the book.) We also hope to prepare a brief interim report, describing the major themes of the workshop, especially the topics for future research.

We will also complete the study of how situation assessment gets *communicated*, as well as the study of team decision errors (generating, we hope, a more carefully worked out taxonomy).

One "new" project is a detailed analysis of the wildland firefighting data. These decision makers were the most skilled we have yet encountered, and we feel that it can be very important to document their training, organizational dynamics, and capabilities.

A second "new" research thrust for Year 2 is an examination of individual decision errors, reviewing data from the studies we have already performed under various sponsorship. We are particularly eager to document ways that a recognitional decision strategy can lead to ineffective performance.

The third activity planned for Year 2 is to study mental simulation in much the way we started our investigations of naturalistic decision making--observations of proficient decision makers working out a conceptual image of what would happen if an option was implemented.

Two other projects are being examined for feasibility. One is the potential for using the ARI database on command-and-control exercises held at the National Training Center. We would like to examine Commander's Intent through these data, and we also want to see if we can document the proportion of intent and goals that are actually implemented during the course of a simulated battle.

The second project is the possibility of studying situation assessment training within the context of an Intensive Care Unit at a hospital in the Dayton area. Since situation assessment training is on the agenda for Year 3, we may want to get a head start and perform some observational research.

SUMMARY

This has been an extremely fast start for the contract. We initiated four studies, rather than the three we had planned. We developed two new models of team decision making. And we conducted a workshop on naturalistic decision making for the leading researchers in this area. We will not keep up this pace during Year 2, but we are feeling very excited about the accomplishments of Year 1, and about their implications for helping us to understand operational decision making.

We would also like to mention some direct applications of our research for ARI. We have consulted with the National Fire Academy, where instructors are beginning to use the RPD model for course presentations on what to expect during crisis decision making. Also, we have had several opportunities to present a training module on crisis decision making at the Central Training Academy, in Albuquerque, New Mexico. The Central Training Academy serves the Department of Energy by providing managerial training to administrators of nuclear production facilities, to help prepare them to deal with accidents, and emergencies such as terrorist attacks.

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Attachments (Papers and publications are attached to original only.)

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